

Measurement of the top quark mass in the all hadronic channel at CDF

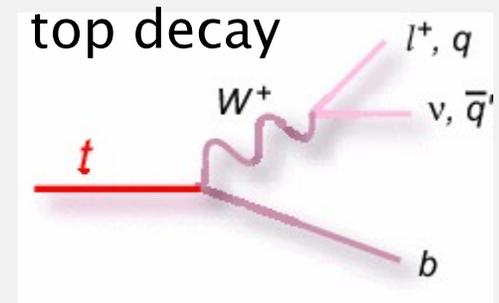
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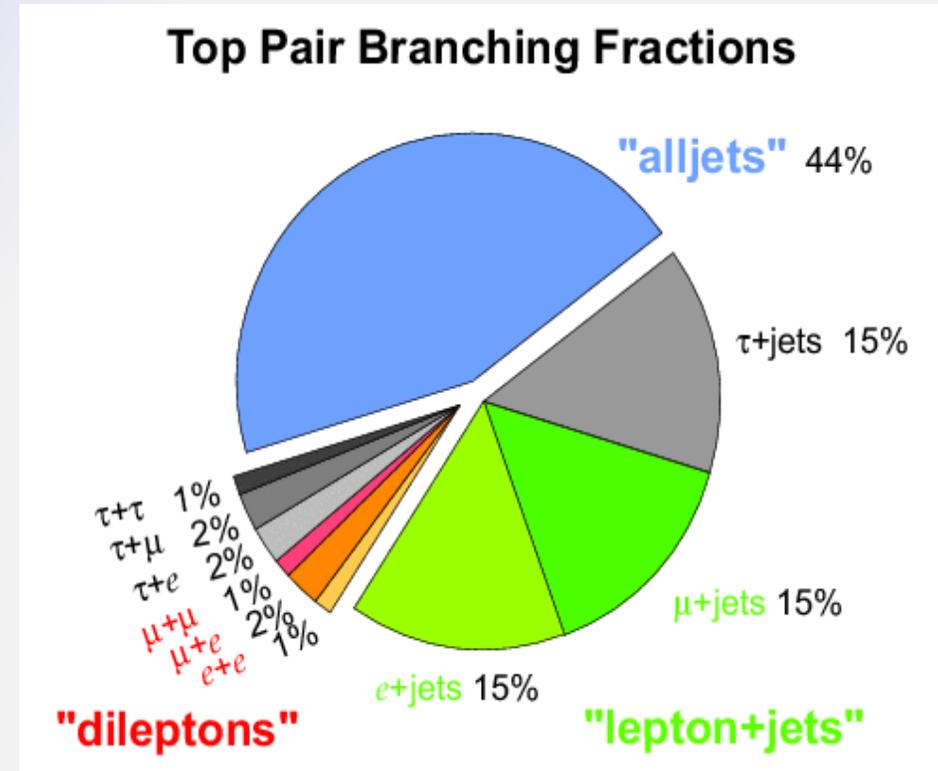
Fermilab User's Meeting 31.5.2006

Top quark

- ★ Most of the time top quarks are produced in pairs
- ★ They decay into W boson and b-quark almost in 100% of the cases
- Topology of $t\bar{t}$ event is defined by the decay of the W bosons

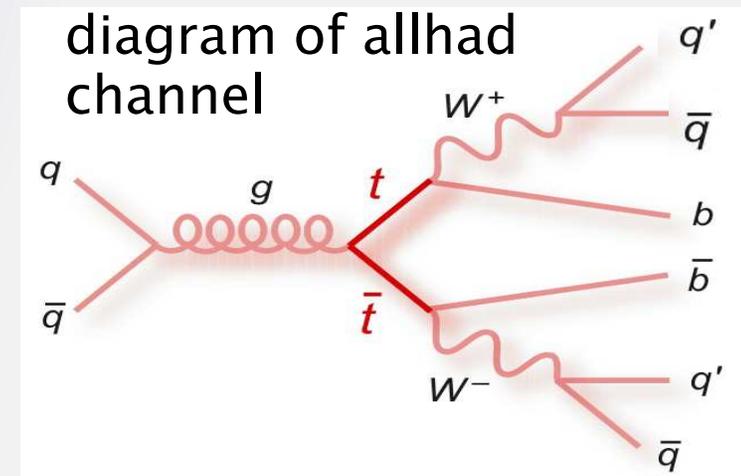


- ★ **dilepton channel:**
 - ★ both Ws decay into lepton and neutrino
- ★ **lepton+jets:**
 - ★ one W decay into two quarks, another into lepton and neutrino
- ★ **all hadronic channel:**
 - ★ both Ws decay into two quarks



The all hadronic top mass at CDF

- 6 or more (due to isr&fsr) jets in the final state
- Large multi jet QCD background, $S/B \sim 1/6$ after event selection
- Background composition and modelling
- Many possible ways to combine jets to top-antitop pair: 90 combinations
- + No neutrinos - Both top quarks can be fully reconstructed



- * CDF Run I Result ($\sim 100 \text{ pb}^{-1}$): $186.0 \pm 11.5 \text{ GeV}/c^2$
- * This analysis uses CDF Run II data amounting to 310 pb^{-1}

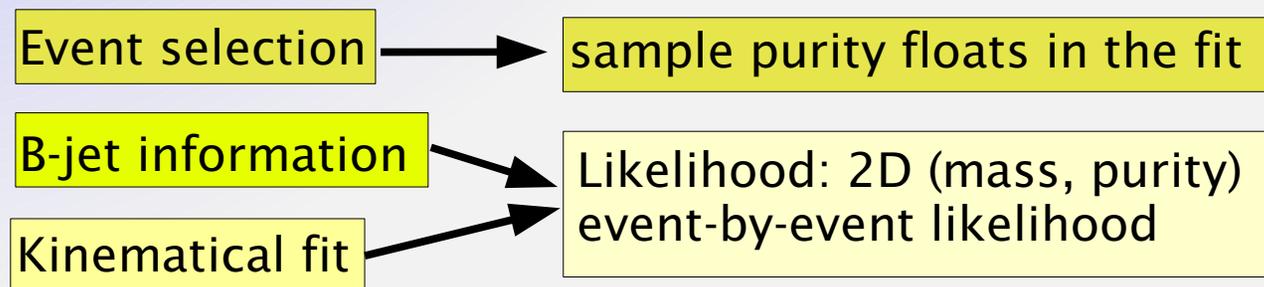
The ideogram method

★ Selection of top candidates

- ★ $E_T^{\text{miss}} / \sqrt{(\sum E_T)} < 3 \text{ (GeV)}^{1/2}$
- ★ $\sum E_T \geq 280 \text{ GeV}$
- ★ $N_{\text{b-tag}} \geq 1$
- ★ Exactly 6 jets

| | Expected Events (310 pb ⁻¹) |
|---------------------------|--|
| Multi-jets (light) | 182 |
| Multi-jets (heavy flavor) | 68 |
| Total background | 250 |
| tt (6.1 pb) | 40 |
| Data | 290 |

★ Ideogram method was developed in DELPHI experiment for W mass measurement



Kinematic fit

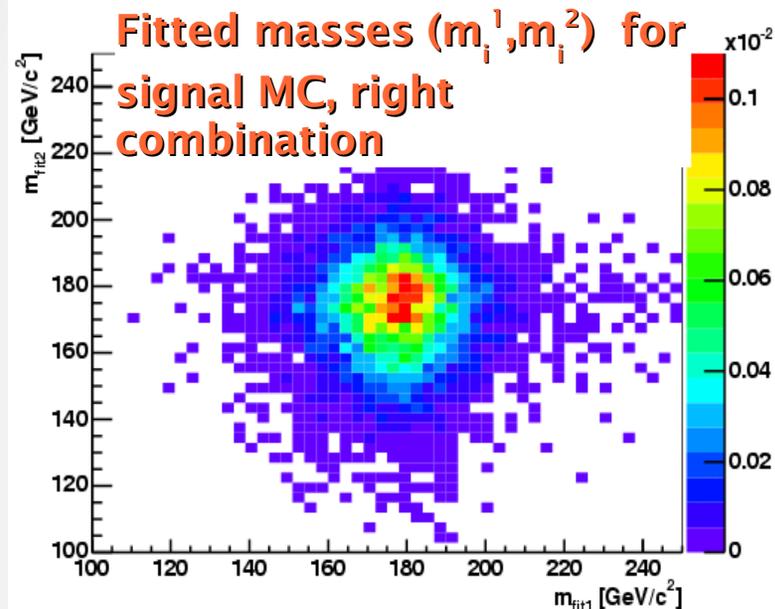
- ★ Improves mass resolution and reduces the background and jet ambiguities
- ★ Kinematic fit minimizes χ_i^2 for every jet combinations (i=1...90)

$$\chi_i^2(m_i^1, m_i^2) = \frac{(m_t^{fit,1} - m_i^1)^2}{\Gamma_t^2} + \frac{(m_t^{fit,2} - m_i^2)^2}{\Gamma_t^2} + \frac{(M_W - M_W^{fit,1})^2}{\Gamma_W^2} + \frac{(M_W - M_W^{fit,2})^2}{\Gamma_W^2} + \sum_{j=1}^6 \frac{(P_{T,j}^{meas} - P_{T,j}^{fit})^2}{\sigma_i^2}$$

Fit two top quark masses, gives good separation between signal and background

Demand that W masses are equal to measured world average

Take into account uncertainties of measured jet momenta



- ★ Obtain fitted masses m_i^1, m_i^2 , their errors $\sigma_{m,i}^1, \sigma_{m,i}^2$, and goodness of fit χ_i^2 that are used later in the likelihood

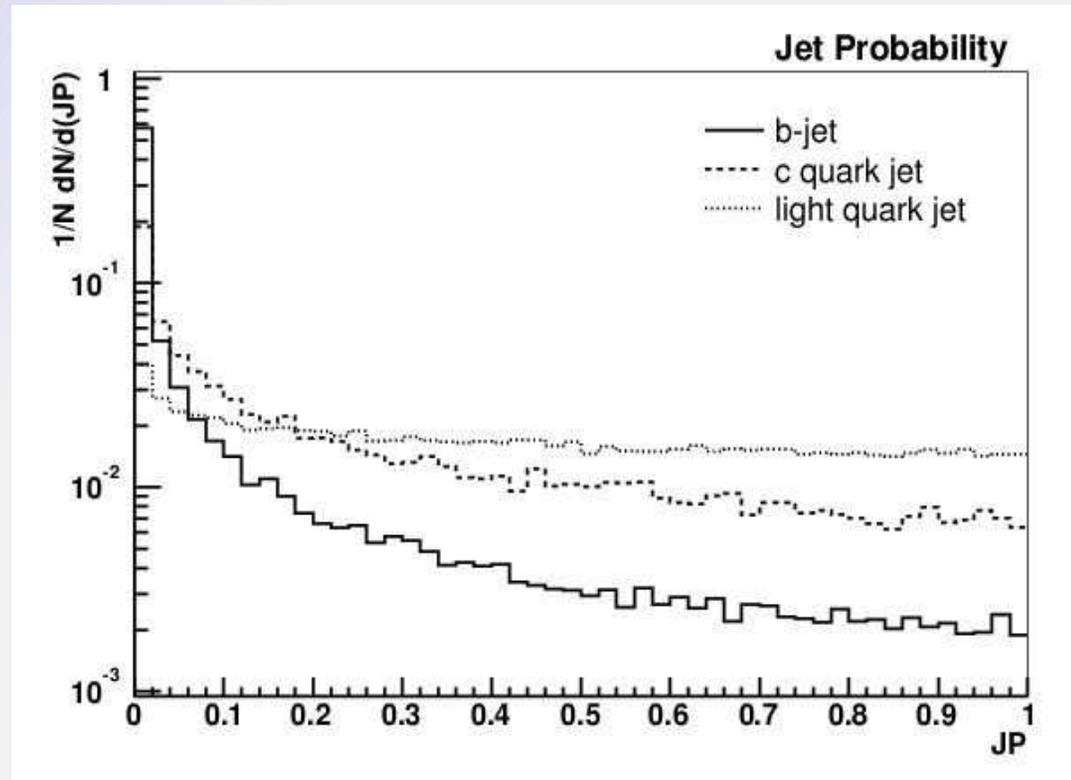
b-jet information

- ★ If the b-quark jets in top decay $t \rightarrow b + W \rightarrow b + q \bar{q}'$ could be identified with 100% efficiency, the amount of jet combinations would reduce to 6
- ★ Jet Probability tagger gives a probability that jet is coming from the primary vertex
- ★ It can be used to define a likelihood to jet be a b-jet or a light quark jet:

$$L(\text{jet is b-jet}) = \frac{P(b|JP)}{P(b|JP) + P(q|JP)}$$

$$L(\text{jet is light flavor jet}) = \frac{P(q|JP)}{P(b|JP) + P(q|JP)}$$

- ★ Test hypothesis for two b-jets and 4 light quark jets

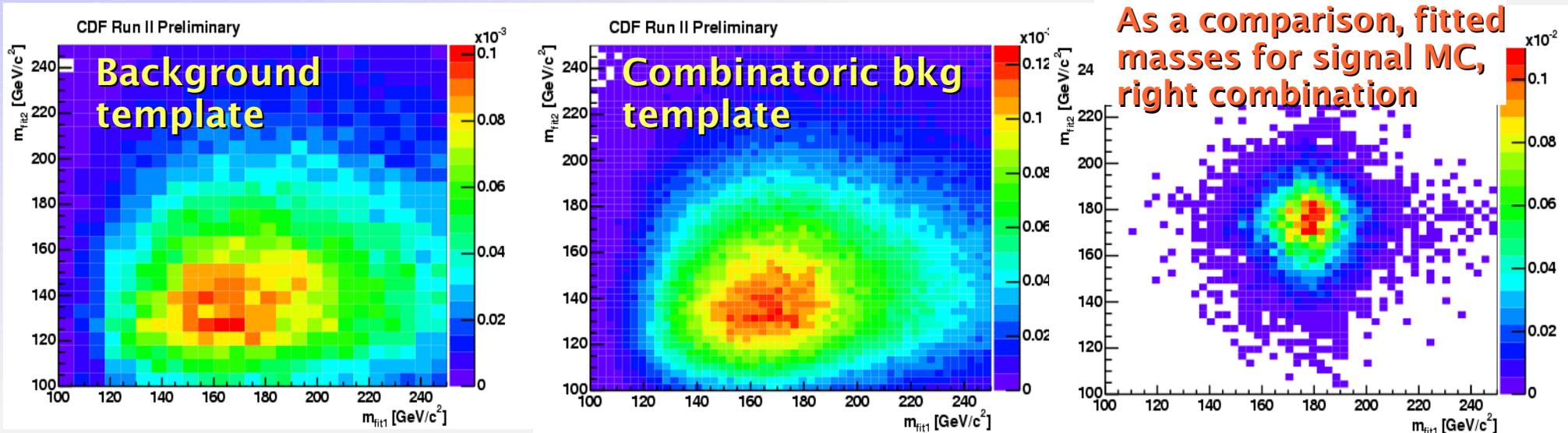


Likelihood function

- ★ The 2D top mass-purity (M_t, P_s) likelihood is defined as

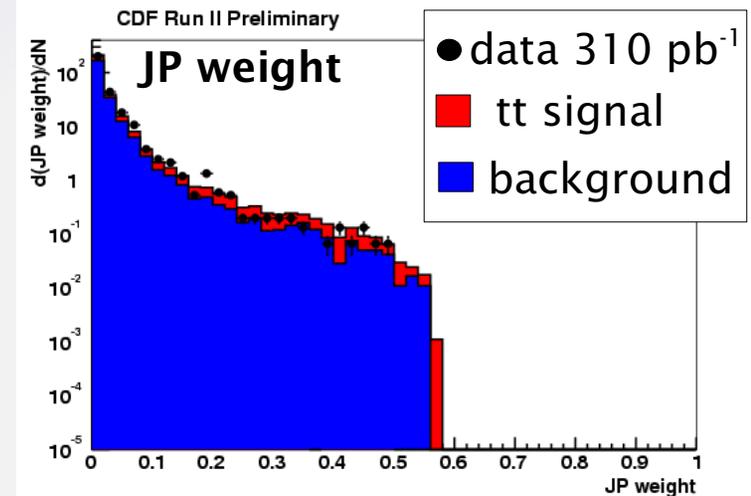
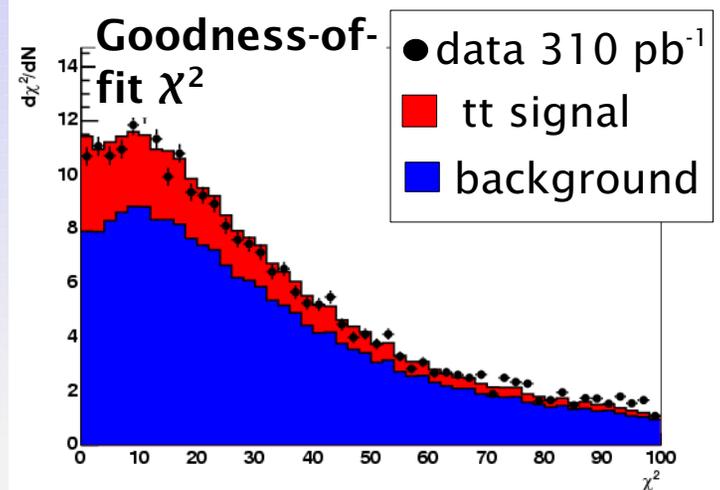
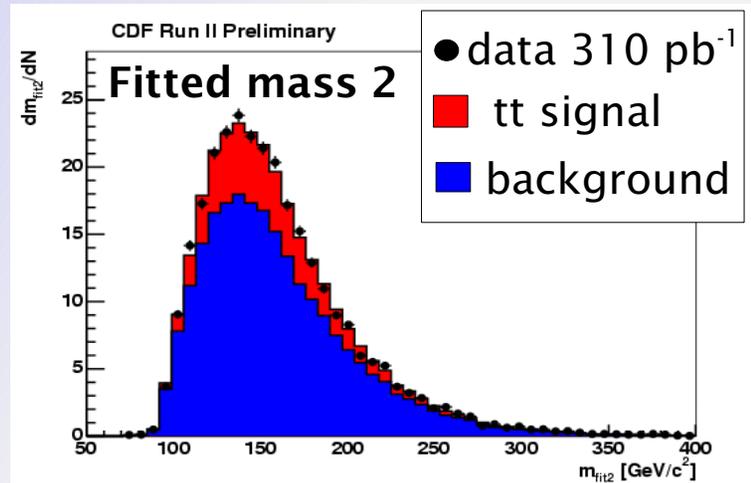
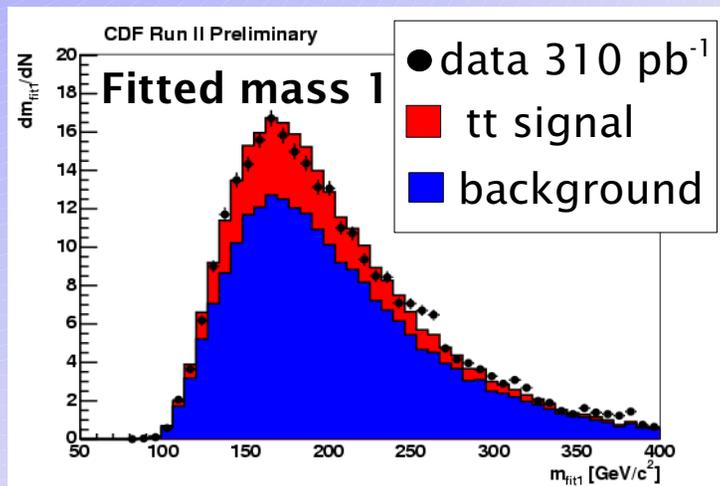
$$L_{evt}(M_t, P_s) = \sum_{i=1}^{90} w_i [P_s \cdot S(m_i^1, m_i^2, \sigma_i^1, \sigma_i^2, M_t) + (1 - P_s) \cdot BG(m_i^1, m_i^2)]$$

- ★ Sum over possible jet permutations, weight each combination using χ^2_i , b-jet information: $w_i = \exp(-\chi^2_i/2) \cdot P_{b-jet}$
- ★ Signal likelihood is a sum of two parts
 - ★ A convolution of Breit-Wigner functions with gaussian resolutions
 - ★ Combinatoric background
- ★ Template is used for the background and combinatoric background



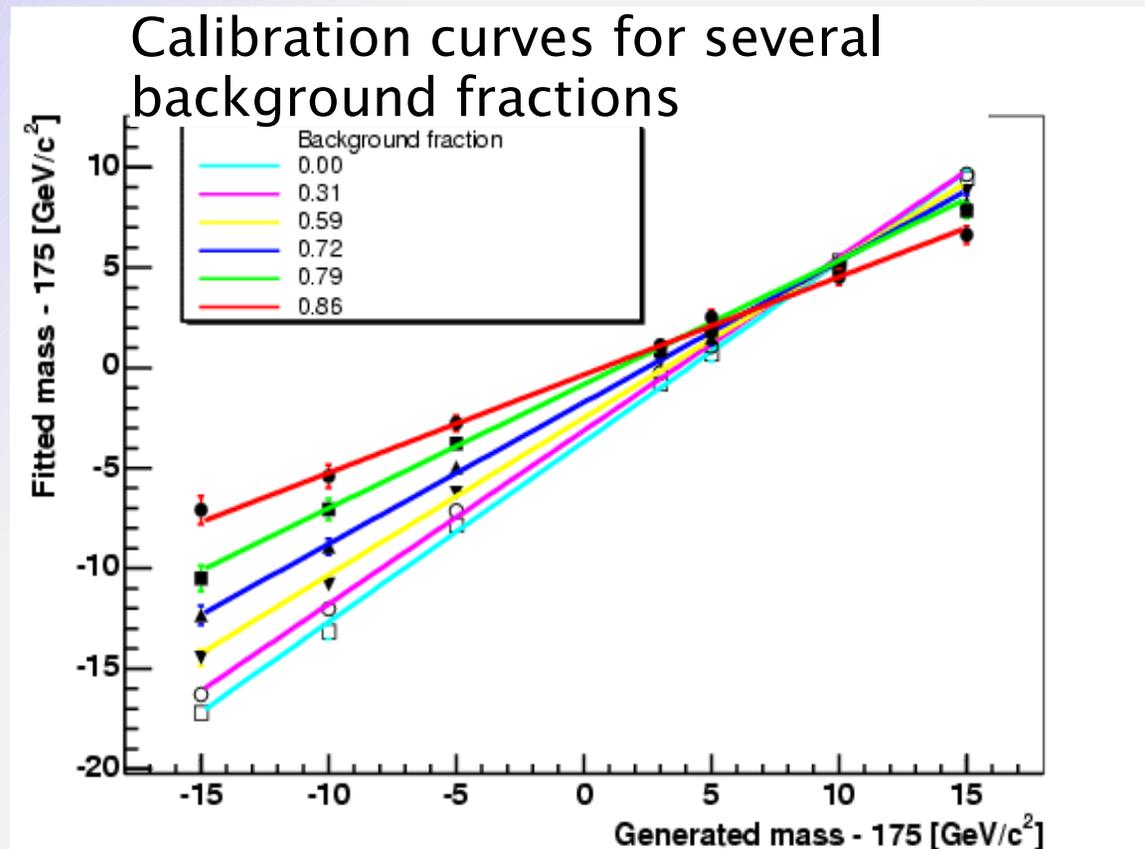
Background

- ★ Many studies were made to be sure that background Monte Carlo reproduces data
- ★ In addition to background Monte Carlo, mistagged data is used to model the background



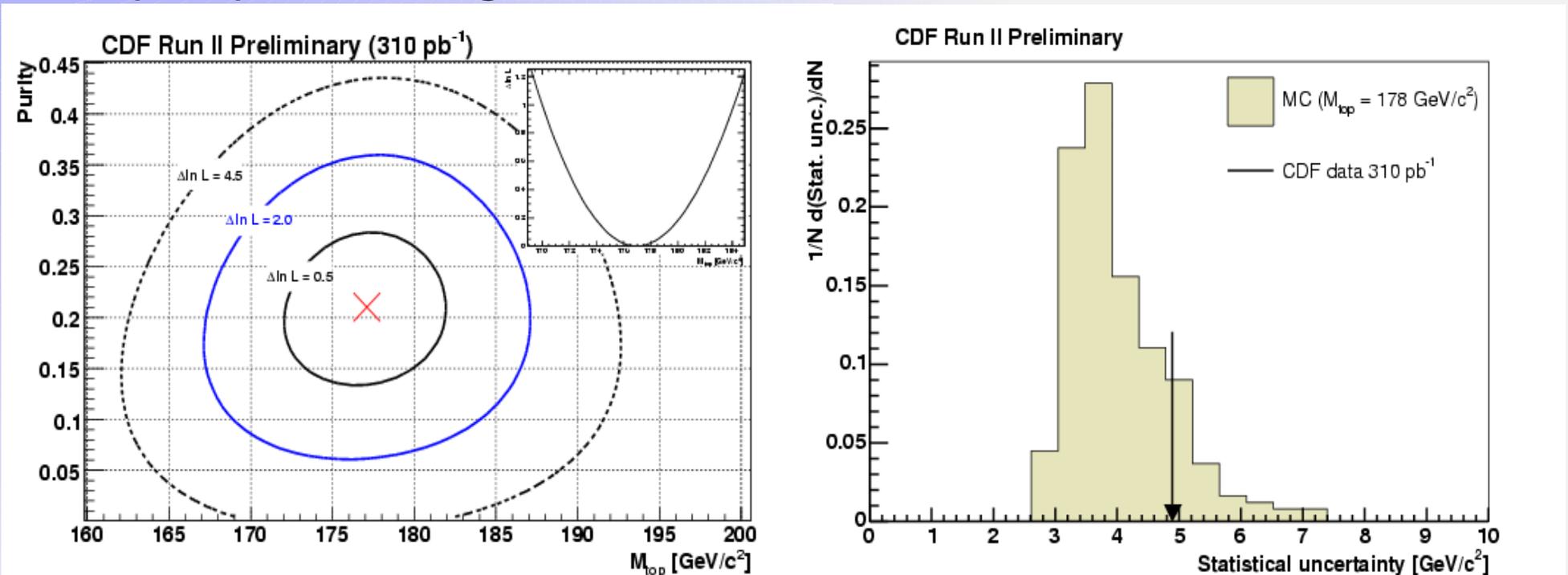
Monte Carlo tests

- ★ We observe a bias due to background and jet combinatorics
 - ★ Bias is corrected using Monte Carlo events
- ★ The statistical uncertainties are underestimated by 17%
 - ★ This is caused by background events
 - ★ We inflate the errors to take this into account
- ★ Expected statistical uncertainties are 4-5 GeV/c^2
- ★ The fitted purity is independent of input M_{top}



Results

- ★ From the observed 290 data events we fit a purity $P_s = 0.21 \pm 0.07$
- ★ It corresponds to 61 ± 20 signal events
- ★ Compatible with the all hadronic cross section measurement and the purity fitted using Monte Carlo



- ★ The measured mass value amounts to

$$M_t = 177.1 \pm 4.9(\text{stat}) \pm 4.7(\text{syst}) \text{ GeV}/c^2$$

- ★ Break down of systematics will follow

Systematic uncertainties

★ The systematic uncertainties have been estimated to be 4.7 GeV/c²

| Source | ΔM_t (GeV/c ²) |
|---------------|------------------------------------|
| JES | 4.3 |
| B-JES | 0.5 |
| Fragmentation | 0.5 |
| ISR | 0.9 |
| FSR | 0.8 |
| PDF | 0.8 |
| BG shape | 0.8 |
| BG fraction | 1.1 |
| Total | 4.7 |

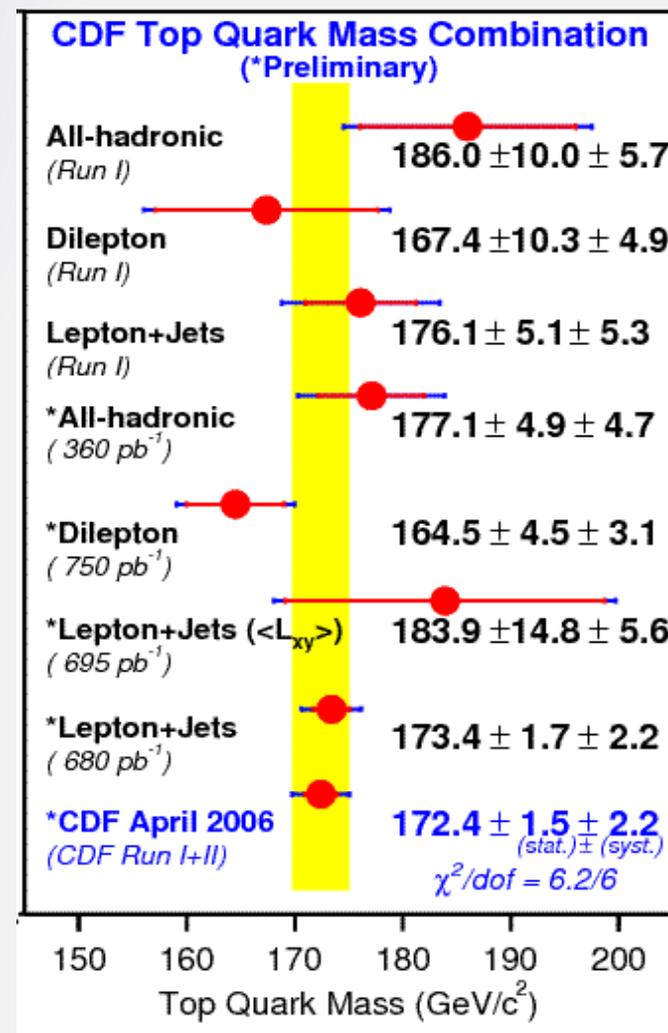
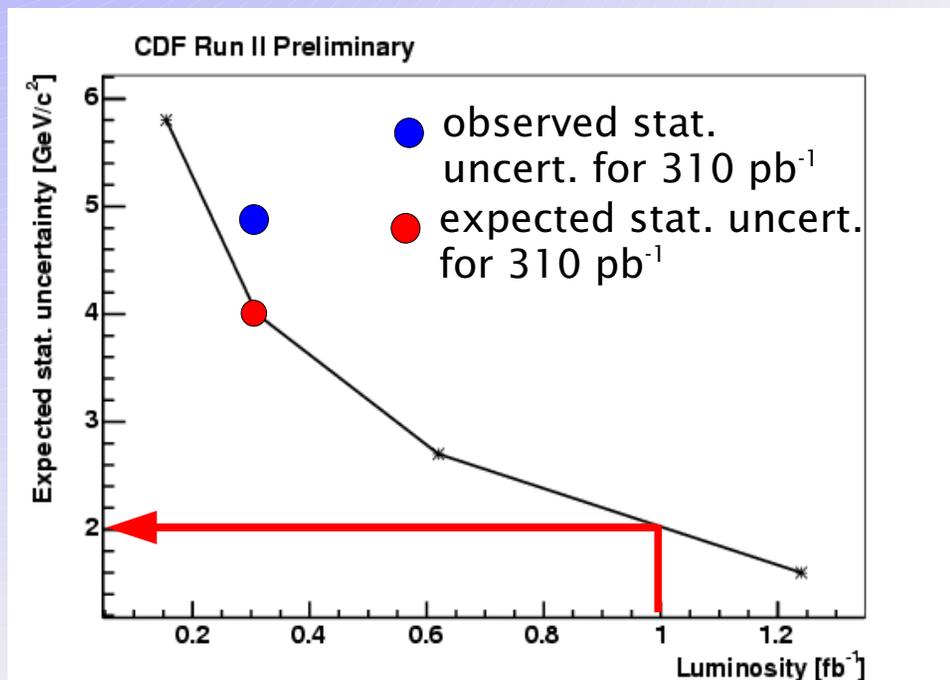
★ The main source is the jet energy scale (JES)

★ Background shape takes into account the uncertainty on background composition

★ Background fraction is due to the uncertainty on fitted signal purity

Summary

- ★ The first Run II top mass measurement in the all hadronic channel
- ★ Statistical sensitivity comparable with the measurements in other channels
- ★ Factor two more precise than Run I result in this channel



- ★ Without improvements to method, we expect to have stat. uncertainties ~2 GeV/c² for 1 fb⁻¹